ROHDE & SCHWARZ

BESCHREIBUNG

INSTRUCT. BOOK

Übersetzung der deutschen Ausgabe R 12874

Zusammengestellt nach R 15811

Printed in Western Germany

Instruction Book

NOISE GENERATOR

Type SKTU

BN 4151/2/50

BN 4151/2/60

BN 4151/2/75

ROHDE & SCHWARZ SALES CO. (U.S.A.) INC.
111 LEXINGTON AVENUE
P. O. BOX 148
PASSAIC, NEW JERSEY (201) 773-8010

Supply of Replacements

Replacements are supplied on request by your nearest R&S agents ore the principals ROHDE & SCHWARZ, D 8000 München 8, Mühldorfstraße 15; telephone (0811) 401981; telex 05-23703; telegram rohdeschwarz muenchen.

In your own interests, please let us have the following specifications when ordering replacements:

(a) Reference Number and R&S Stock Number of the defective component (according to parts list).

(b) Type or Order Number (BN) and Serial Number (FNr.) of the equipment (e. g. according to front-panel engravings).

Please specify the exact address in order to avoid unnecessary delays in delivery.

"Zusammenstell-Vorschrift"

The "Zusammenstell-Vorschrift" is a reference list specifying the different parts of the instruction book. With the aid of this list (ZV), it is possible to check up on the latest amendment (ÄZ) of the parts lists, circuit diagrams and drawings, and to find out whether all specified parts are in fact included in the instruction book.

Sections that are missing in the instruction book but listed in the "Zusammenstell-Vorschrift" were either not available when the instruction book was compiled or have been omitted unintentionally. Please inform us in this case, indicating the reference number (R-Nr.) of the list in the lower right-hand corner and the item number (Pos. -Nr.).

Table of Contents

1. Characteristics

1.1 General and Uses

Noise is caused by random phenomena which consist of a large number of non-periodic single events (pulses). White noise is characterized by an infinitely dense spectrum; hence, every possible frequency is present. The instantaneous amplitudes deviate from the average value for a single spectral line or for spectral lines in a given frequency band. The number of deviations may be determined with the aid of probability theory. For white noise, the average values for the spectral lines must be constant in an infinitely narrow frequency band, independent of the frequency. This requirement proves that white noise cannot be present over the entire frequency range but only over a wide frequency range or the noise power would become infinite. Noise in four-terminal networks is an unwanted power which is calculated to obtain the noise figure. It is best determined by means of a generator which supplies white noise in the frequency range of interest. The use of such a generator makes for rapid measurements without the need for additional calculations, the test results permitting sensitivity comparisons on different receivers, amplifiers etc.

The Noise Generator Type SKTU is ideal for this type of measurement in the frequency range 1 to 1000 MHz. The noise power of the SKTU, which can be continuously adjusted, is ample for receiver measurements. The SKTU comes in three models with 50, 60 and 75 Ω output impedance.

1.2 Specifications

	BN 4151/2/50	BN 4151/2/60	BN 4151/2/75
Frequency range	1 to 1000 MHz	1 to 1000 MHz	1 to 1000 MHz
Output impedance	50 Ω	60 Ω	75 Ω
VSWR	< 1.1	< 1.1	< 1.1
Noise power	continuously adjustable		
Maximum variation of the noise power at ±10% AC supply voltage fluctuation (the accuracy of the measurement remains unaffected)	≤ ±2.5%	≤ ±2.5%	≤ ±2.5%
Noise-figure ranges	1 to 6.5 1 to 33	1 to 8 1 to 40	1 to 6.4 1 to 32
	corresponding to		
	0 to 8 dB 0 to 15 dB	0 to 9 dB 0 to 16 dB	0 to 8 dB 0 to 15 dB
Error of indication			
in the frequency range up to 300 MHz	≤ ±0.5 dB	≤ ±0.5 dB	≤ ±0.5 dB
in the frequency range above 300 MHz	≤ ±1 dB	≤ ±1 dB	≤ ±1 dB

Output . . . . R&S connector Dezifix B, adaptable (tubular base)+)

AC supply . . . . 115/125/220/235 V, 47 to 63 Hz (25 VA)

Active components . . . . 3 transistors, 1 valve

Dimensions . . . . 470 x 195 x 260 mm (R&S Standard Cabinet 45)

Weight . . . . 9 kg

Order designation . . . . Noise Generator Type SKTU
BN 4151/2/50 (50-Ω model)
BN 4151/2/60 (60-Ω model)
BN 4151/2/75 (75-Ω model)

+) With the aid of screw-in assemblies the user can easily adapt this connector to other systems.

1.3 Definition of the Noise Figure

The noise figure F is the ratio of the signal-to-noise power ratio at the input to that at the output of a four-terminal network.

$$F = \frac{S_1/N_1}{S_2/N_2} = \frac{N_2}{G_o N_1}$$

where

S_1	signal power at the input
$S_2 = S_1 G_o$	signal power at the output
N_1	noise power at the input
N_2	noise power at the output
G_o	power gain

The noise figure is therefore by definition a non-dimensional quantity.

$N_1 = kT_o\Delta f$ is the noise power due to the source impedance under the assumption that the temperature of the generator source is equal to the standard noise temperature T_o.

Then $$F = \frac{N_2}{kT_o \; \Delta f G_o}$$

where

N_2	output noise power in W
k	Boltzmann's constant
T_o	standard noise temperature (≈ absolute room temperature)
Δf	effective noise bandwidth in Hz
G_o	power gain
kT_o	4×10^{-21} Wsec.

According to this definition, the total noise power at the output is referred to the amplified reference power of 1 $kT_o\Delta f$. The output noise power N_2 is composed of this amplified reference power and

the component produced by the noisy four-terminal network. Thus the noise figure can be split up:

$$F = \frac{G_o N_1 + N_z}{G_o N_1} = 1 + \frac{N_z}{G_o N_1} = 1 + F_z$$

where F_z represents the contribution of the noisy four-terminal network. F_z is 0 for a noiseless four-terminal network, hence $F = 1$. Lower values are not possible.

The definition of the noise figure is based on the assumption that only the linear transmission range of the four-terminal network is used in the measurement. Non-linearity would seriously alter the noise spectrum and thus lead to measurement errors.

Often it is preferable to specify the noise figure in dB.
<u>Noise figure in dB:</u>

$$F_{dB} = 10 \log. F.$$

For conversion of the noise figure from F to F_{dB} and vice versa, see Fig. 1.

Translations for Fig. 1

Bild 1 Zusammenhang zwischen Rauschzahl und Rauschmaß	Fig. 1 Conversion of noise figure from F to F_{dB} and vice versa
Rauschmaß	Noise figure in dB
Rauschzahl	Noise figure

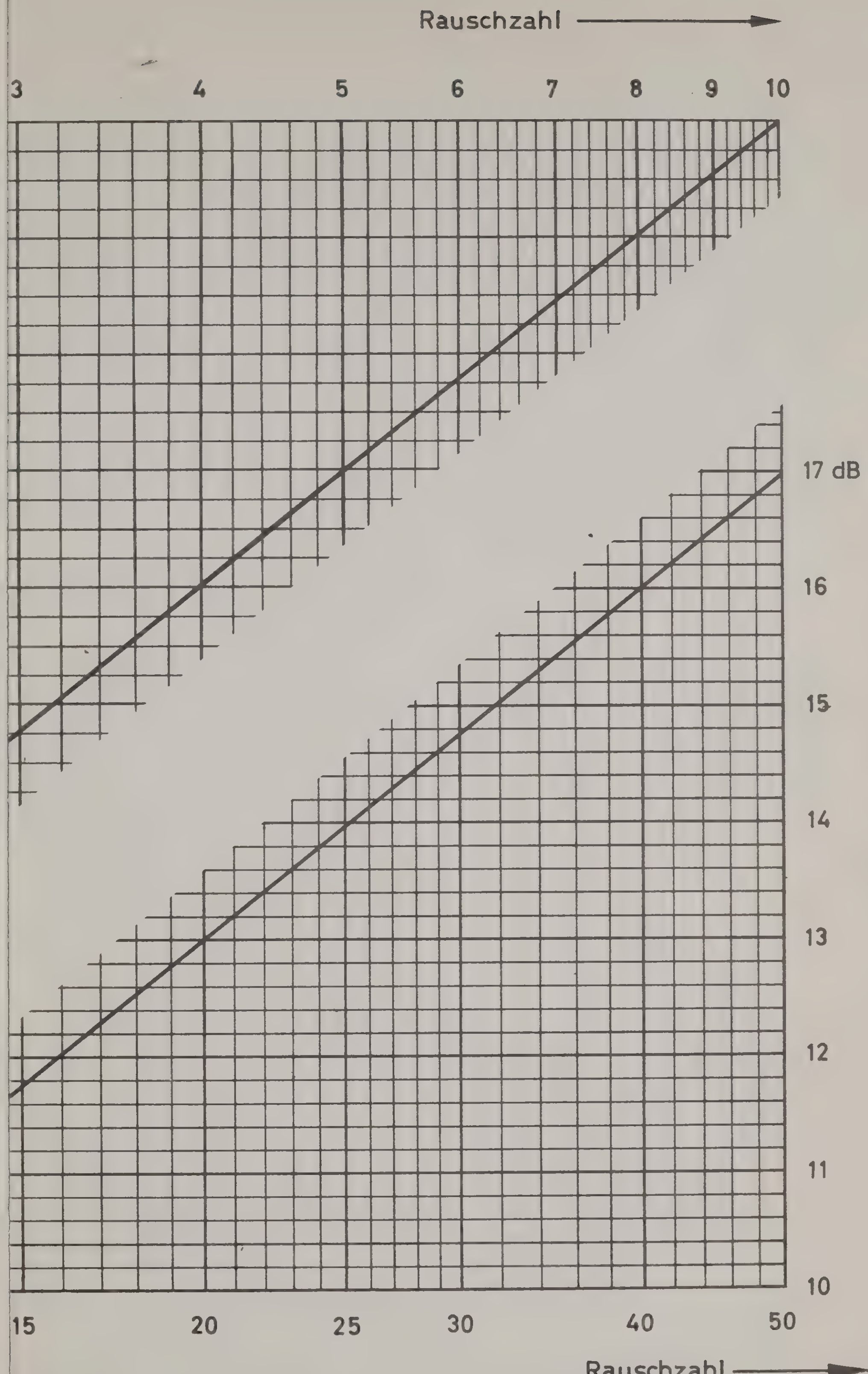


Bild 1 Zusammenhang zwischen Rauschzahl und Rauschmaß

12874
8

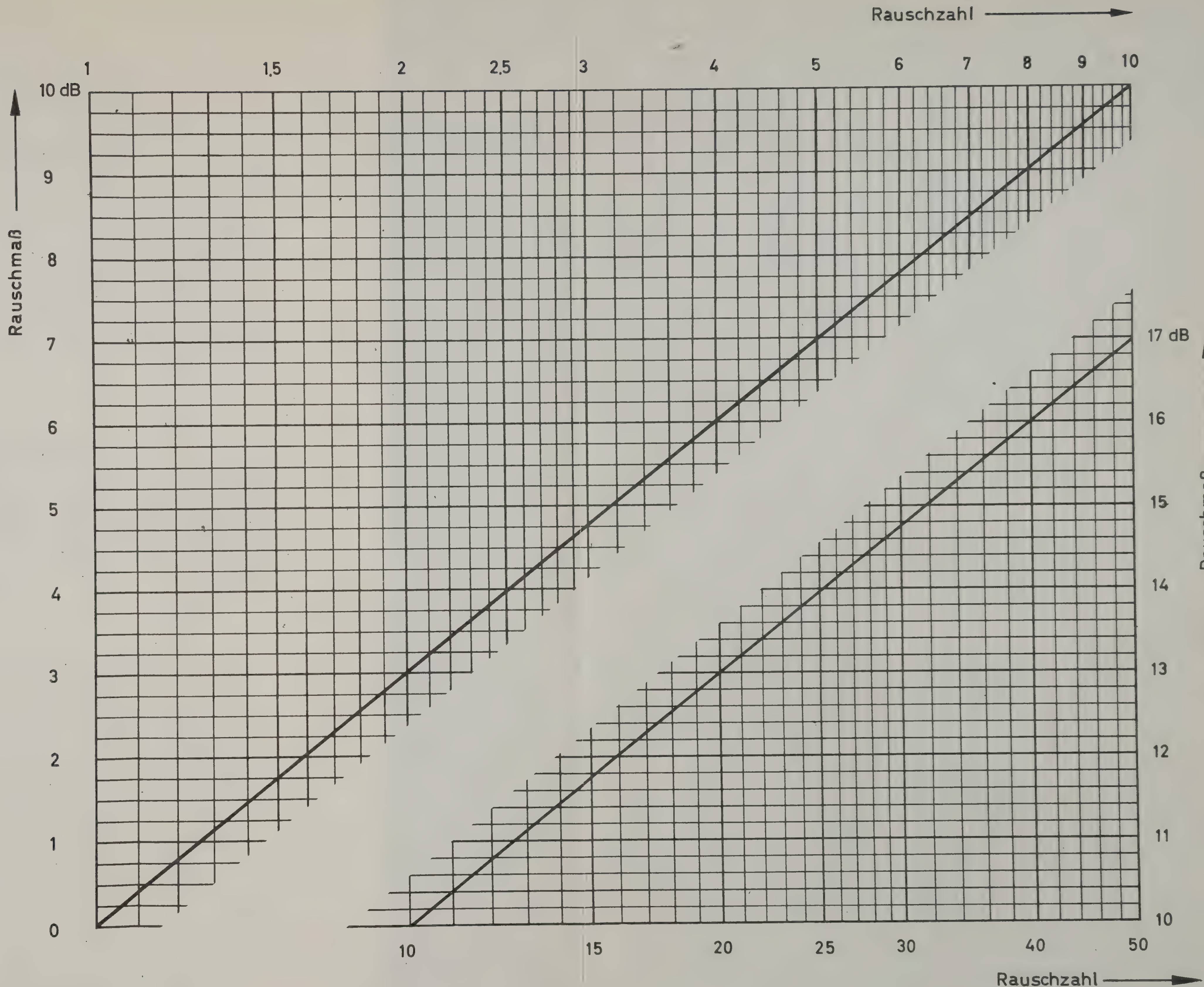


Bild 1 Zusammenhang zwischen Rauschzahl und Rauschmaß

2. Preparation for Use and Operating Instructions

2.1 Adjusting the Set to the Local Supply Voltage

Type SKTU is factory-adjusted for operation from a 220-V AC supply. To adjust it for operation from 115, 125 or 235 V, unscrew the cheese-head screws at the corners of the front panel, withdraw the chassis from its cabinet and insert a suitable microfuse into the pairs of clips on the tapping panel marked with the given supply voltage. The 0.4-amp fuse provided for 220 V will also do for 235 V. If the local power supply is 115 or 125 V, insert a 0.8-amp fuse (M 0,8 C DIN 41571).

2.2 Setting the Mechanical Zero on the Meter

With the set switched off, the pointer should be on the mechanical zero (noise figure = 0). The slotted screw recessed in the meter housing serves to correct the pointer position, if necessary. This is also possible with the set switched on provided the noise power control is turned fully counterclockwise.

2.3 Cable Connection between Type SKTU and Receiver

The output of the Type SKTU is fitted with an R&S connector Dezifix B which is adaptable to other connector systems. The adaptation procedure is very simple: Unscrew the outer conductor of the Dezifix connector using the wrench FZM 10900 and remove the inner conductor with the aid of a 4-mm screwdriver. Insert the inner and the outer conductors of the required screw-in assembly. The following screw-in assemblies are available:

Required connectors for Type SKTU	Order Number
50-Ω socket UHF series (MIL)	FHD 10900/50
50-Ω plug UHF series (MIL)	FHS 10900/50
50-Ω socket N series (MIL)	FHD 20900/50
50-Ω plug N series (MIL)	FHS 20900/50
75-Ω socket N series (MIL)	FHD 20900/75
75-Ω plug N series (MIL)	FHS 20900/75
50-Ω socket C series (MIL)	FHD 30900/50
50-Ω plug C series (MIL)	FHS 30900/50
50-Ω socket BNC series (MIL)	FHD 40900/50
50-Ω plug BNC series (MIL)	FHS 40900/50
50-Ω socket 4.1/9.5	FID 20900/50
50-Ω plug 4.1/9.5	FIS 20900/50
50-Ω socket 7/16	FID 40900/50
50-Ω plug 7/16	FIS 40900/50
60-Ω socket 3.5/9.5	FID 20900/60
60-Ω plug 3.5/9.5	FIS 20900/60
60-Ω socket 6/16	FID 40900/60
60-Ω plug 6/16	FIS 40900/60
50-Ω connector 874 General Radio	FLA 20900/50
50-Ω connector H 4 Marconi	FLB 20900/50

Great care should be taken when storing Dezifix connectors and screw-in assemblies since even slight mechanical damage may affect their electrical characteristics.

2.4 Switching On

Put the toggle switch, which is located over the AC supply input, up for on. The glow lamp connected to the primary winding of the power transformer serves as a voltage indicator.

The set is ready for operation immediately after switching on. For maximum life of the noise diode, turn the noise power control to minimum output when not measuring.

2.5 Range Selection

To ensure good readability of the noise output adjusted, two different meter ranges can be selected with a toggle switch on the left-hand side of the front panel. The switch labelling refers to the associated full-scale deflection.

2.6 Test Setup and Measuring Procedure

A suitable test setup is shown in Fig. 2. The output of the SKTU is connected to the input of the test item with a short cable. The characteristic impedance of this cable corresponds to the output impedance of the test item and the SKTU. Noise figures can be measured within the linear transmission range of the test item. The meter must, therefore, be connected after the linear section. The adjustable attenuator connected between the meter and the output of the test item should be matched to the output impedance of the test item and the input impedance of the meter. Now check that the deflection on the meter is large enough when the noise power control is switched off (meter of the SKTU on 0). A standard attenuator, which inevitably exhibits a certain residual attenuation, may be used for the adjustment. Increase the attenuation by 3 dB and then feed enough noise power from the SKTU to the input of the test item until the same deflection is obtained as before. The output noise power is doubled, i.e. the signal power equals the noise power of the test item. This corresponds to the determination of the noise figure (cf. section 2.10) which can be read directly as a ratio or in dB on the meter of the SKTU. This measuring method avoids errors which might be introduced by a non-linear meter characteristic.

It is also possible to obtain a reading on a meter without the use of an attenuator. In this case, however, it is necessary to make sure that the deflection change actually corresponds to a power increase of 3 dB.

2.7 Determining the Noise Figure at any Desired Signal-to-noise Ratio

It will not always be possible to use an increase of 3 dB, i.e. double the power. Even though the noise figure is defined for this ratio, other ratios are permissible for the measurement (cf. section 2.10). The actual noise figure is then found by a simple calculation from the noise figure indicated on the SKTU. The ratios are compiled in Table A where N_2 is the power which is present at the output of the linear section of the test item, without additional noise power being fed in from the SKTU; S_2 is the amplified power resulting from the additional noise fed into the input of the test item from the SKTU; N_{tot} corresponds to the sum of $N_2 + S_2$. U_{tot} and U_2 are the voltages pertaining to N_{tot} and N_2, respectively. F is the actual noise figure, F' is the noise figure read off the Noise Generator SKTU. The frame in the centre of the table refers to the measuring procedure described, in which S_2 must equal N_2 and N_{tot} must equal $S_2 + N_2 = 2N_2$. In this case, the actual noise figure corresponds to the indicated noise figure. If the additionally applied noise power is increased so that the basic value at the output is exceeded, the actual noise figure is below the value indicated and vice versa.

Table A

$\frac{S_2}{N_2}$	$\frac{N_{tot}}{N_2}$	$\frac{N_{tot}}{N_2}$ in dB	$\frac{U_{tot}}{U_2}$	$\frac{F}{F'}$	$F_{dB} - F'_{dB}$ in dB
0.2	1.2	0.79	1.095	5.0	+6.99
0.4	1.4	1.46	1.18	2.5	+3.98
0.6	1.6	2.04	1.264	1.67	+2.22
0.8	1.8	2.55	1.34	1.25	+0.97
1.0	2.0	3.01	1.41	1.0	0
2.0	3.0	4.77	1.73	0.5	-3.0
3.0	4.0	6.02	2.0	0.33	-4.77
4.0	5.0	6.99	2.24	0.25	-6.02
5.0	6.0	7.78	2.45	0.2	-6.99

2.8 Noise Measurements on Systems

Usually, signal-to-noise ratios are measured on complete systems (AM or FM). This measuring method may also be employed for noise measurements even though non-linearities are likely to occur in the signal channel. It depends, however, whether these non-linearities affect the signal or not. If the signal at the output of a four-terminal network (in which mixing, limiting etc. occur) is a linear function of the input signal, the totel transmission path of the signal is linear and it is possible to carry out noise-figure measurements. It is, however, necessary that the signal-to-noise ratio in the system is in fact based on the input noise. For this reason, it is imperative that hum components and interfering heterodynes are eliminated or considerably reduced below the level of the noise.

The measurement of the noise figure of such a system is illustrated by a measurement on an FM receiver. Fig. 3a shows a common test setup for measuring the signal-to-noise ratio. A signal generator is used to feed the useful signal (modulated for the signal-voltage, unmodulated for the noise-voltage measurement) to the receiver. The noise voltmeter connected to the AF output of the receiver measures the noise level. The test result is shown in Fig. 3b. The signal level and the noise level are plotted vs. the RF input level. In region A, the transition from the minimum input level to the initiation of the limiter action, takes place, beyond which the signal level remains constant, independent of the RF input level. The noise level falls off in region B. This is shown in Fig. 3c. The carrier is assumed to be modulated with a noise spectrum which, on account of its statistical distribution, causes amplitude and phase modulation represented by AM and FM noise in the AF section. The FM noise comes from the noise phase deviations. While AM and FM noise occurs in region A of Fig. 3b, there is no AM noise beyond the initiation of the limiter action. The noise phase deviation decreases as the carrier voltage increases since the noise power at the input remains constant. A signal-to-noise ratio increasing linearly with the input level results. In region C, effects other

than those of the input noise occur, for instance, increase of the inherent noise referred to the input by the initiation of the gain-control action. There is no longer a linear relation between input level and signal-to-noise ratio. In region B, it is possible to measure the noise figure. A suitable test setup is shown in Fig. 3d in which Type SKTU is connected directly to the FM receiver. Satisfactory decoupling to avoid mismatch and interaction is provided when feeding in the signal generator signal to the FM receiver. The fed-in power must be large enough to ensure that an indication in the linear region B (Fig. 3b) is obtained.

For noise figure measurements, an additional noise power is fed to the receiver input from the SKTU to raise the indication on the noise voltmeter by 3 dB. The noise figure of the receiver can then be read on the scale of the SKTU.

This method is still valid, even though the AM component of the noise from the SKTU has been eliminated by the limiter, because the AM noise of the receiver is rejected also. Furthermore, the noise distribution is statistical and so in fact, equal parts of the AM and FM noise occur. From this it can be seen that an analagous method can be employed for AM systems where the AM detector eliminates the FM noise.

2.9 Determination of the Total Noise Figure from the Noise Figures of Four-terminal Sections

The total noise figure of several series-connected four-terminal networks with a power gain of G_1, G_2 to G_m is given by (cf. Fig. 4)

$$F_{tot} = F_1 + \frac{F_{z2}}{G_1} + \frac{F_{z3}}{G_1 G_2} + \ldots \frac{F_{zn}}{\prod_{m=1}^{m=n-1} G_m}$$

An attenuator pad is also a four-terminal network and its noise figure can be found with the aid of Fig. 5.

The resistance network should always be matched. The signal power available at the output is then attenuated by G. The noise power N_1, which depends on R_1, remains unchanged, however, as the generator output resistance and the input resistance of the network, observed from the terminating resistor, are both R_1.

$$F_w = \frac{\frac{S_1}{N_1}}{\frac{G\ S_1}{N_1}} = \frac{1}{G}\ .$$

If the attenuation network is noise-free (Fig. 6) the noise figure is 1 (Fig. 7).

$$F_w = \frac{\frac{S_1}{N_1}}{\frac{G\ S_1}{G\ N_1}} = 1.$$

If a resistive attenuator pad is connected to the input of a receiver (Fig. 8) the noise figure worsens according to:

$$F_{tot} = F_w + \frac{F_2-1}{G_1} = \frac{1}{G_1} + \frac{F_2-1}{G_1} = \frac{F_2}{G_1}\ .$$

If an attenuator pad is interconnected (Fig. 9) the total noise figure.

$$F_{tot} = F_1 + \frac{F_w-1}{G_1} + \frac{F_3-1}{G_1G_2} = F_1 + \frac{1}{G_1G_2} - \frac{1}{G_1} + \frac{F_3-1}{G_1G_2} = F_1 + \frac{1}{G_1}\left(\frac{F_3}{G_2} - 1\right).$$

If an attenuator pad is connected to the output of a system (Fig. 10) noise figure increases according to:

$$F_{tot} = F_1 + \frac{F_w - 1}{G_1} = F_1 + \frac{1}{G_1 G_2} - \frac{1}{G_1} = F_1 + \frac{1}{G_1}\left(\frac{1}{G_2} - 1\right) .$$

If this noise figure is derived using signal-to-noise ratios the following should be borne in mind (Fig. 11):

The four-terminal networks must be matched. The output impedance of the four-terminal network V_1, therefore, is R_1. This resistor delivers the noise power N_1, which is part of the additional noise power $N_Z = N'_Z + N_1$, to the terminating resistor R_1. The attenuator pad V_2, connected between $R_i = R_1$ and the output of V_1, delivers the output noise power (N_1) to R_i, independent of the attenuation if the attenuator pad input is terminated by the (noisy) output impedance. The other components $G_1 S_1$; $G_1 N_1$ and $N_Z - N_1$ which are available at the output of V_2 are attenuated by G_2. Hence the total noise figure becomes:

$$F_{tot} = \frac{\dfrac{S_1}{N_1}}{\dfrac{G_1 G_2 S_1}{G_1 G_2 N_1 + G_2 (N_Z - N_1) + N_1}} = \frac{G_1 G_2 N_1 + G_2 N_Z}{G_1 G_2 N_1} + \frac{N_1 (1 - G_2)}{G_1 G_2 N_1}$$

$$= F_1 + \frac{1}{G_1 G_2} - \frac{1}{G_1} = F_1 + \frac{1}{G_1}\left(\frac{1}{G_2} - 1\right).$$

If identical four-terminal networks are connected in parallel under matched conditions the total noise figure depends on the noise figure of the individual networks. This is demonstrated in Fig. 7.

If, however, only the inputs are connected in parallel and the outputs are used as independent channels the following noise figure (see Fig. 7) is obtained (two channels):

$$F = \frac{S_1}{N_1} \times \frac{N_2}{S_2} = \frac{U_s^2}{R_i} \times \frac{R_i}{U_R^2} \times \frac{\frac{v^2U_R^2}{2R_a} + \frac{U_z^2}{R_a}}{\frac{v^2U_s^2}{2R_a}} = \frac{U_s^2}{U_R^2} \times \frac{\frac{v^2U_R^2}{2} + U_z^2}{\frac{v^2U_s^2}{2}} = 1 + \frac{2U_z^2}{v^2U_R^2} = 1 + 2F_z$$

$$= F_o + F_z = 2F_o - 1.$$ (F_o = noise figure of the individual four-terminal network)

For more channels an analagous result is obtained. In the following example a preamplifier is used for channel splitting as in multi-couplers (Fig. 12). It is necessary that the matched conditions are maintained or that mismatch does not noticeably falsify the noise figures of the four-terminal networks. n is the portion of the total power that flows into the series-connected four-terminal network under consideration.

$$F_{tot} = \frac{G_2 \frac{G_1N_1 + N_{z1}}{n} + N_{z2}}{\frac{G_1}{n} G_2N_1} = \frac{G_1N_1 + N_{z1}}{G_1N_1} + \frac{n\,N_{z2}}{G_1G_2N_1} = F_1 + n\frac{F_{z2}}{G_1} = F_1 + n\frac{F_2 - 1}{G_1}$$

2.10 Correlation of the Noise Figure and the Required Input Voltage

The definition of noise figure makes no assumptions about how the signal power is produced. It is possible to derive the signal from a signal generator operating at a discrete frequency and to compare the applied signal power with the power of the noise spectrum still present at the output because of the response pass band. For the calculation of this noise power the "effective" bandwidth must be known. The effective bandwidth Δf of an amplifier system (see Fig. 13) is found by integrating the squared effective output noise voltage, which is proportional to the power over the entire noise spectrum, and dividing this integral by the maximum noise power $^{2}_{max}$:

$$\Delta f = \frac{1}{\alpha_{max}^{2}} \int_{\omega=0}^{\omega=\infty} [\alpha(\omega)]^{2} \, d\omega.$$

where α = effective noise voltage depending on the frequency

α_{max} = maximum effective noise voltage

The open-circuit signal voltage U_o which must be applied to the receiver in order to obtain a signal-to-noise ratio of 1 can be determined if, in addition to the noise figure F, the effective noise bandwidth Δf and the input impedance of the receiver R_e, equal to the source impedance of the generator, are known:

$$U_o = \sqrt{4F \times kT_o \times f \times R_e}.$$

For example, a receiver with $R_e = 60\ \Omega$, $\Delta f = 10^6$ Hz and $F = 5$ requires an open-circuit signal voltage

$$U_o = \sqrt{4 \times 5 \times 4 \times 10^{-21} \times 10^6 \times 60}\ \mathrm{V} = 2.2 \times 20^{-6}\ \mathrm{V} = 2.2\ \mu\mathrm{V}.$$

The nomogram provided in the upper left-hand corner of the front panel permits the receiver input voltage to be read in µV so obtaining the signal-to-noise ratio 1 at the measured noise figure and given receiver bandwidth.

The cumbersome determination of the actual bandwidth is avoided if the signal power is derived from a noise source that supplies a wide spectrum of white noise. The signal from this source covers the bandwidths by which the noise spectrum of the input is limited and so their significance is eliminated.

To determine the noise figure, only N_2 (cf. page 6) need be measured since the reference value 1 kT_o is a known quantity. Apply a power which, for example, causes the noise power at the output to be doubled (signal-to-noise ratio = 1) to the input of the four-terminal network. If the power available at the input is known divide it by reference power and the result obtained is the noise figure F. If the generator used for the measurement of the noise figure is calibrated in kT_o, it gives a direct reading of the noise figure F. The measurement may, of course, also be based on other signal-to-noise ratios. For measuring very high noise figures the available generator power is often insufficient and ratios of < 1 will have to do even though the accuracy may be affected. The noise figure F' determined with other power ratios and read off the generator is related with the actual noise figure F as follows:

$$F = \frac{S_1/N_1}{S_2/N_2} = \frac{S_1/N_1}{\frac{N_{tot} - N_2}{N_2}} = \frac{S_1/N_1}{\frac{N_{tot}}{N_2} - 1} = \frac{F'}{\frac{N_{tot}}{N_2} - 1} = F' \frac{N_2}{S_2};$$

where S_1 = signal power at the input; N_{tot} = $S_2 + N_2$

S_2 = signal power at the output; F = actual noise figure

N_1 = noise power at the input; F' = measured noise figure

N_2 = noise power at the output;

This relationship is shown in Table A (page 12).

2.11 Errors

To avoid measuring errors it is imperative to check the following points:

Unwanted pick-up

Pick-up of radio signals from broadcast transmitters and of sweep generator signals must at all times be avoided. These unwanted signals may easily get into the receiver channel which is adjusted to its maximum sensitivity for noise measurements. It is, therefore, possible that relatively low spurious signal levels considerably falsify measurements. If the spurious signal level is of the order of the noise level then the original, i.e. the noise level to be measured, is doubled and the noise power which must be applied for measuring the noise figure must also be correspondingly increased. This leads to a noise figure reading which is twice as high as the real noise figure of the receiver.

Absolute protection against unwanted pick-up is provided by a screened room which will seldom be available. It is therefore indispensable to check that there is no unwanted pick-up and this is best accomplished by monitoring the receiver. A good test-setup minimizes the danger of unwanted pick-up and,above all, the connecting cable between the SKTU and the test item should be short and closely braided (double-screened cable).

Attenuation at the input

Any attenuation at the input of an amplifier - perhaps a lossy cable - causes a noise figure reading higher than the actual noise figure of the amplifier.

AGC

Receivers with automatic gain control must be handled differently. If the control action is initiated within the range of the noise

level used an error would be introduced in the noise figure measurement as the additionally applied noise power would be treated like a signal. The amplification would no longer be linear so that the requirement of measuring after the linear section could not be fulfilled. It is therefore advisable to switch off the automatic gain control during noise figure measurements.

Non-linearities

Non-linearities, which affect the signal, shift the distribution of the noise spectrum due to the mixing processes and this gives rise to erroneous measurements.

DC input isolation

Instruments with the input isolated to DC do not cause measurement errors. With other equipment, however, the DC voltage appearing at the output of the SKTU can falsify measurements if it reaches an active device. It may, for example, shift the operating point of an amplifier and lead to detuning of the test item. A blocking capacitor or a short circuit via a parallel-connected inductance, which in the measurement range has a high impedance with respect to the characteristic impedance, helps to avoid this effect. This precaution is seldom required since most often the receiver input contains tuned circuits and consequently DC short circuits or blocking capacitors which interrupt the DC path.

Mismatch

For noise figure measurements the output of the noise generator is connected to the input of the four-terminal network under test. The output impedance of the noise generator must be matched to the nominal characteristic impedance of the four-terminal network. The noise figure of an amplifier generally depends on

the circuitry at the input, hence also on the output impedance of the connected generator. Therefore, the measurement must be made using the generator output impedance at which the set is to be operated (e.g., simulation of the antenna impedance with the output impedance of the SKTU when connecting to a receiver).

When the influence of the generator output impedance on the noise figure of the test item is negligible - this is the case with receiver input stages where matching is not critical and the deviation of the impedance is not excessive - a discrepancy in the generator output impedance R_o from the terminating resistance R_a used in practice, causes an error of

$$\frac{N'}{N} = 4 \times \frac{R_a R_o}{(R_a + R_o)^2} ;$$

If $R_o = 50\ \Omega$ and $R_a = 60\ \Omega$, the resulting error is < 1%.

Since the noise diode supplies an impressed current, the output impedance is critical for the available power. If it deviates from the nominal value, the power deviation is given by

$$\frac{N'}{N} = \left(1 + \underline{r}_i\right)^2$$

where N' = actually available noise power;

N = nominal available noise power;

$\underline{r}_i$ = complex reflection coefficient of the output impedance.

If, for example, the noise power is required accurate to 1% the output impedance of the SKTU must not deviate more than 1% from the nominal value.

Indicator characteristic

Check that the application of noise from a noise generator, such as the SKTU, indeed doubles the noise power and increases the indication by 3 dB. For different ratios see section 2.7.

All calibrated attenuators should be matched to ensure that the attenuation is exact for all settings. Moreover, mismatch of the test item should be avoided as it can affect the input impedance of the test item and thus the actual noise figure measurement. This danger exists rarely for receiver measurements where the output is taken from the IF amplifier. In the case of single stages, in particular, of transistor amplifier stages, the termination has a considerable effect on the input impedance and may thus falsify the measurement.

Image frequency rejection

With wideband systems the input selectivity is sometimes insufficient to prevent noise from being picked up at the image frequency. This leads to erroneous noise figure measurements as the noise figure will be worse than the value measured. As the received signal is proportioned to the signal channel only, so must the noise spectrum passing through the test item be limited to the wanted pass band. If one takes the extreme case where no preselection is provided it can be seen that with a white noise source, noise power at the image frequency will be added to that from the signal channel. Consequently, the 3 dB increase in noise power for the measurement will be achieved with half the generator power required for a true reading. The noise figure measured will therefore be half the actual value.

The SKTU can still be used for such measurements providing that a filter is interposed to limit the noise spectrum to the signal channel.

Translations for Figs. 2 to 13

Bild 2	**Fig. 2**
Empfohlener Meßaufbau	Recommended test setup
Anzeige	Meter
Ausg.	Output
Eichleitung	Attenuator
Eing.	Input
Meßobjekt (linearer Teil)	Test item (linear section)
R_i	R_o

Bild 3	**Fig. 3**
a) Anordnung zur Messung des Rauschabstandes	a) Test setup for measuring the signal-to-noise ratio
b) Meßergebnis der Anordnung nach Bild 3a	b) Test result of setup in Fig. 3a
c) Vektorielle Darstellung der Modulation	c) Vectorial representation of the modulation
d) Anordnung zur Rauschzahlmessung	d) Test setup for measuring the noise figure
AM-Rauschen	AM noise
Einkoppelsonde (Entkopplung ca. 40 dB)	Coupling probe (Decoupling approx. 40 dB)
Empfänger	Receiver
FM-Empfänger	FM receiver
Geräuschpegel	Noise level
Geräusch-Spg.-Messer	Noise voltmeter
HF-Eingangspegel	RF input level
Nutzpegel	Signal level
Pegel	Level

Rauschphasenhub = FM-Rauschen	Noise phase deviation corresponding to FM noise
Signal-Generator	Signal generator
Träger	Carrier

<u>Bild 4</u>	<u>Fig. 4</u>
Rauschzahl bei der Kettenschaltung von Vierpolen	Noise figure of series-connected four-terminal networks
Gesamtrauschzahl F_{ges}	Total noise figure F_{tot}
Signal/Rauschverhältnis	Signal-to-noise ratio
Vierpolrauschzahl	Noise figure of four-terminal network

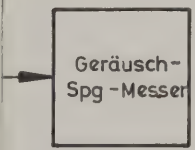
<u>Bild 5</u>	<u>Fig. 5</u>
Widerstandsnetzwerk	Resistance network

<u>Bild 6</u>	<u>Fig. 6</u>
rauschfrei	Noise-free

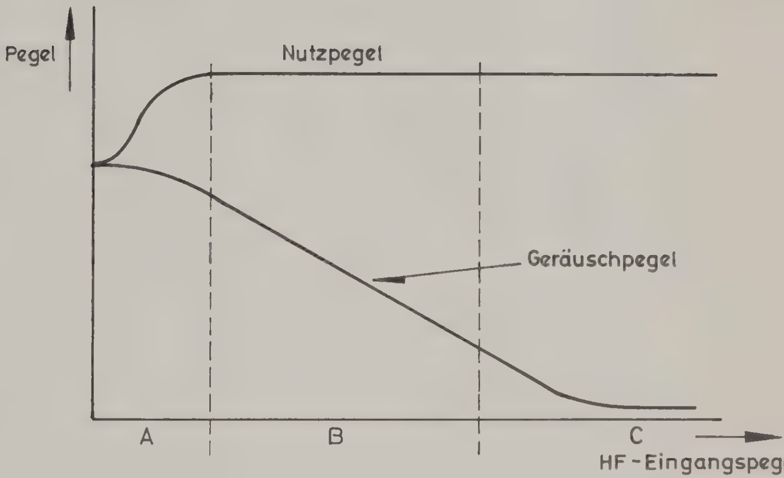
<u>Bild 7</u>	<u>Fig. 7</u>
Rauschverhalten von Vierpolen	Noise behaviour of four-terminal networks
korreliert	Correlated
nicht korreliert	Not correlated
Rauschzahl des Grundvierpols	Noise figure of basic four-terminal network

Rauschzahl parallel geschalteter, gleichartiger Vierpole	Noise figure of parallel-connected, identical four-terminal networks
V = Spannungsverstärkung	V = voltage gain
verlustlos	Loss-free
<u>Bild 8</u>	<u>Fig. 8</u>
Empfänger	Receiver
Dämpfungsglied	Attenuator pad
<u>Bild 9</u>	<u>Fig. 9</u>
Dämpfungsglied.	Attenuator pad
<u>Bild 10</u>	<u>Fig. 10</u>
Dämpfungsglied	Attenuator pad
<u>Bild 11</u>	<u>Fig. 11</u>
<u>Bild 12</u>	<u>Fig. 12</u>
<u>Bild 13</u>	<u>Fig. 13</u>
Ersatz - Rechteckkurve mit α^2_{max}.	Square characteristic corresponding to α^2_{max}
Gegebene Kurve des Quadrates der Amplitudenwerte	Curve of squared amplitude

ßaufbau

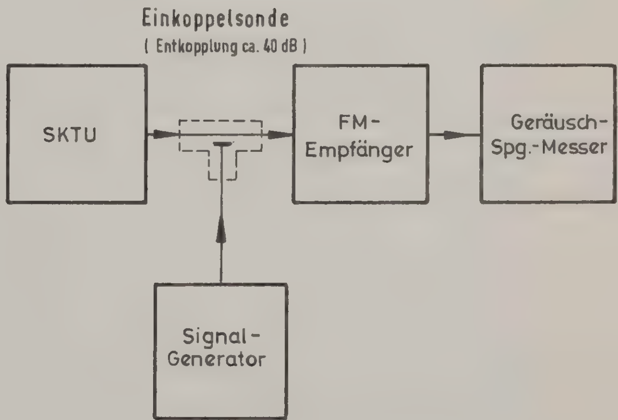


des Rauschabstandes



b) Meßergebnis der Anordnung nach Bild 3a

hasenhub ≙ FM-Rauschen



d) Anordnung zur Rauschzahlmessung

r Modulation

Bild 3

Bild 2 und 3

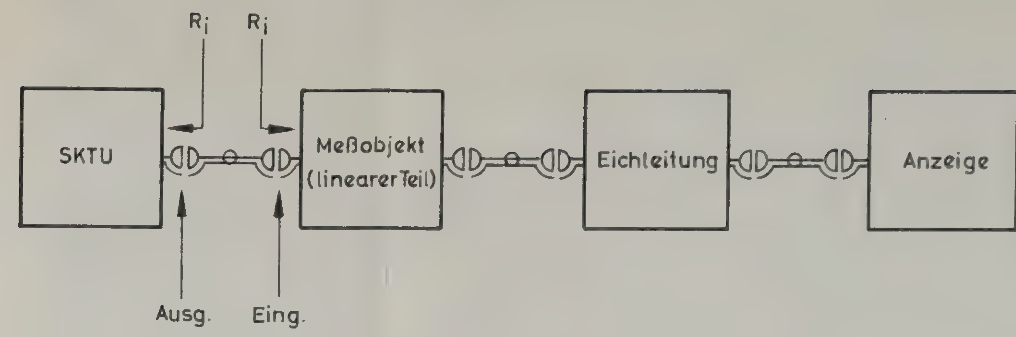
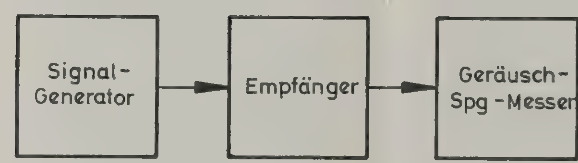
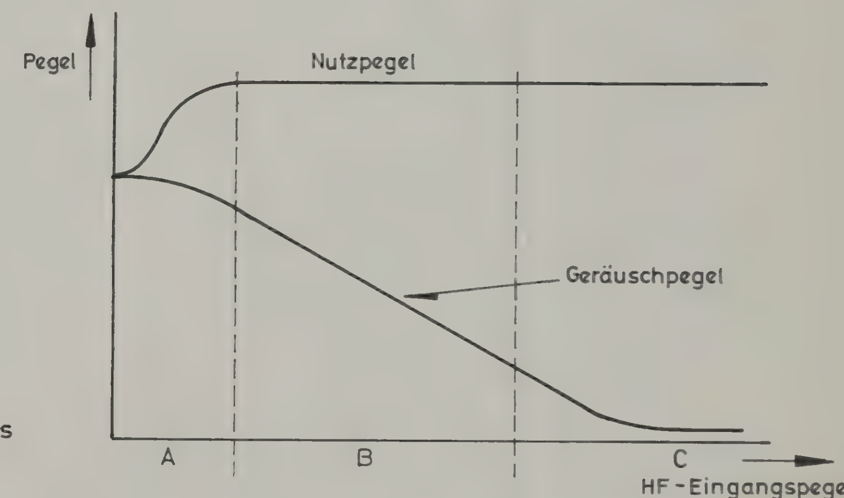


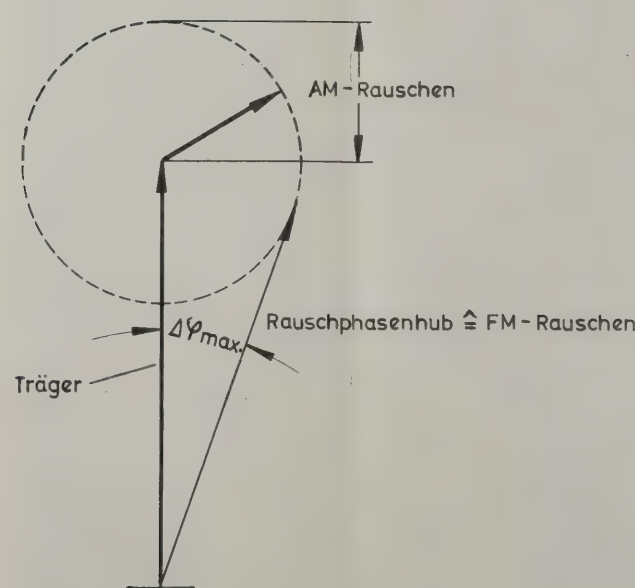
Bild 2 Empfohlener Meßaufbau



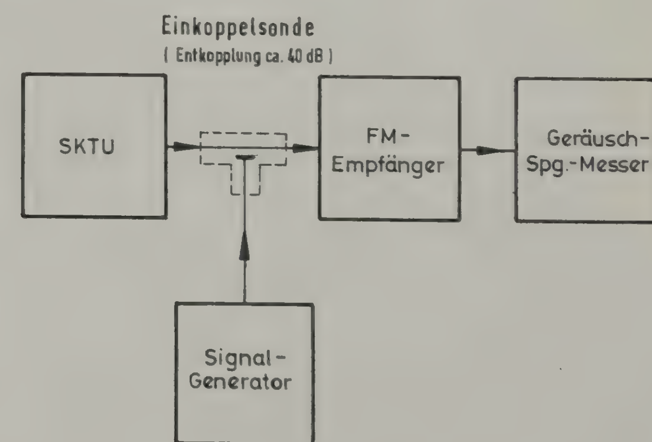
a) Anordnung zur Messung des Rauschabstandes



b) Meßergebnis der Anordnung nach Bild 3a



c) Vektorielle Darstellung der Modulation



d) Anordnung zur Rauschzahlmessung

Bild 3

$$\frac{G_3\left[G_2(G_1N_1+N_{Z1})+N_{Z2}\right]+N_{Z3}}{G_1G_2G_3N_1}$$

$$\frac{G_4\left\{G_3\left[G_2(G_1N_1+N_{Z1})+N_{Z2}\right]+N_{Z3}\right\}+N_{Z4}}{G_1G_2G_3G_4N_1}$$

$$F_4 = \frac{G_4N_1+N_{Z4}}{G_4N_1} = 1+F_{Z4}$$

$$F_n = \frac{G_nN_1+N_{Z n}}{G_nN_1} = 1+F_{Z n}$$

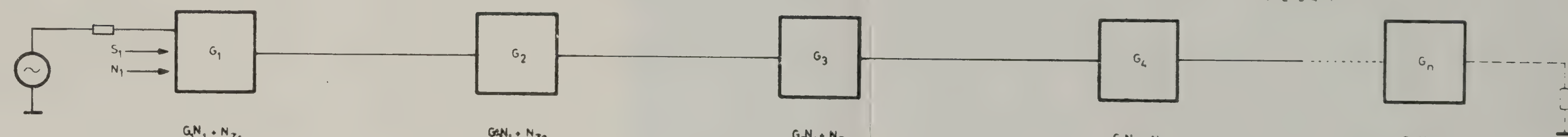
$$\frac{G_3\left[G_2(G_1N_1+N_{Z1})+N_{Z2}\right]+N_{Z3}}{G_1G_2G_3N_1} = F_1+\frac{F_{Z2}}{G_1}+\frac{F_{Z3}}{G_1G_2}$$

$$\frac{G_4\left\{G_3\left[G_2(G_1N_1+N_{Z1})+N_{Z2}\right]+N_{Z3}\right\}+N_{Z4}}{G_1G_2G_3G_4N_1} = F_1+\frac{F_{Z2}}{G_1}+\frac{F_{Z3}}{G_1G_2}+\frac{F_{Z4}}{G_1G_2G_3}$$

Bild 4 Rauschzahl bei der Kettenschaltung von Vierpolen

Signal / Rauschverhältnis

$$\frac{S_1}{N_1} \qquad \frac{G_1N_1 + N_{Z_1}}{G_1N_1} \qquad \frac{G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}}{G_1G_2N_1} \qquad \frac{G_3\left[G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}\right] + N_{Z_3}}{G_1G_2G_3N_1} \qquad \frac{G_4\left\{G_3\left[G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}\right] + N_{Z_3}\right\} + N_{Z_4}}{G_1G_2G_3G_4N_1}$$



Vierpolrauschzahl

$$F_1 = \frac{G_1N_1 + N_{Z_1}}{G_1N_1} = 1 + F_{Z_1} \qquad F_2 = \frac{G_2N_1 + N_{Z_2}}{G_2N_1} = 1 + F_{Z_2} \qquad F_3 = \frac{G_3N_1 + N_{Z_3}}{G_3N_1} = 1 + F_{Z_3} \qquad F_4 = \frac{G_4N_1 + N_{Z_4}}{G_4N_1} = 1 + F_{Z_4} \qquad F_n = \frac{G_nN_1 + N_{Z_n}}{G_nN_1} = 1 + F_{Z_n}$$

Gesamtrauschzahl F_{ges}

$$\frac{G_1N_1 + N_{Z_1}}{G_1N_1} = F_1$$

$$\frac{G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}}{G_1G_2N_1} = F_1 + \frac{F_{Z_2}}{G_1}$$

$$\frac{G_3\left[G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}\right] + N_{Z_3}}{G_1G_2G_3N_1} = F_1 + \frac{F_{Z_2}}{G_1} + \frac{F_{Z_3}}{G_1G_2}$$

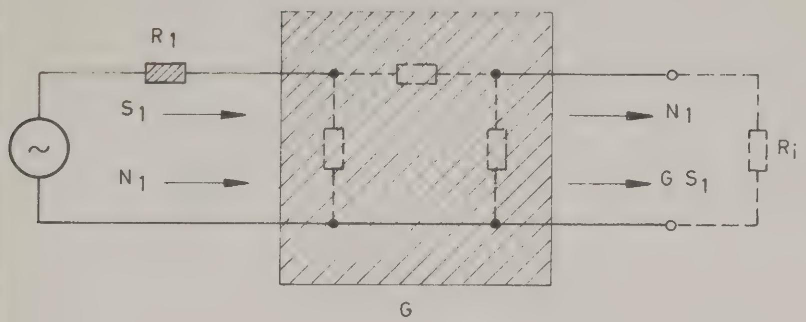
$$\frac{G_4\left\{G_3\left[G_2(G_1N_1 + N_{Z_1}) + N_{Z_2}\right] + N_{Z_3}\right\} + N_{Z_4}}{G_1G_2G_3G_4N_1} = F_1 + \frac{F_{Z_2}}{G_1} + \frac{F_{Z_3}}{G_1G_2} + \frac{F_{Z_4}}{G_1G_2G_3}$$

Bild 4 Rauschzahl bei der Kettenschaltung von Vierpolen

R 12874
Bl. 26

Bild 4

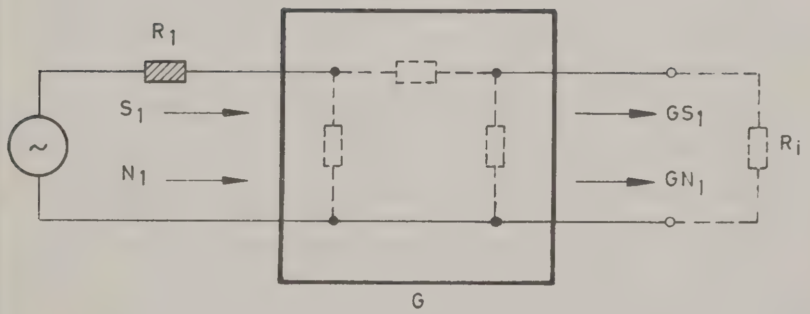
Widerstandsnetzwerk



R 1
S 1
N 1
N 1
G S 1
R i
G

Bild 5

rauschfrei



R 1
S 1
N 1
GS 1
GN 1
R i
G

Bild 6

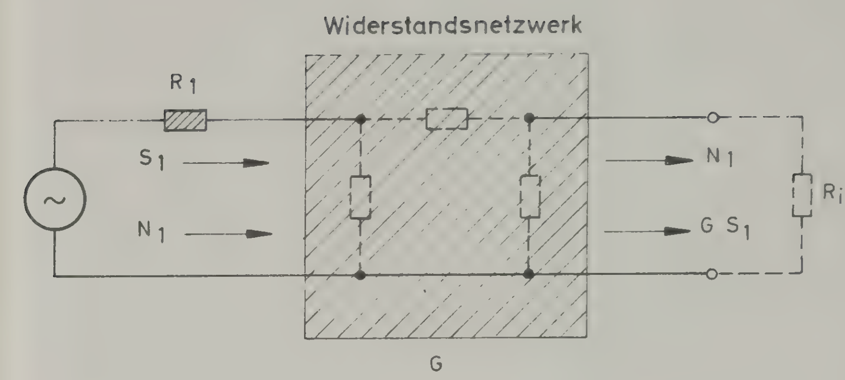

Widerstandsnetzwerk
R1
S1
N1
N1
G S1
Ri
G

Bild 5

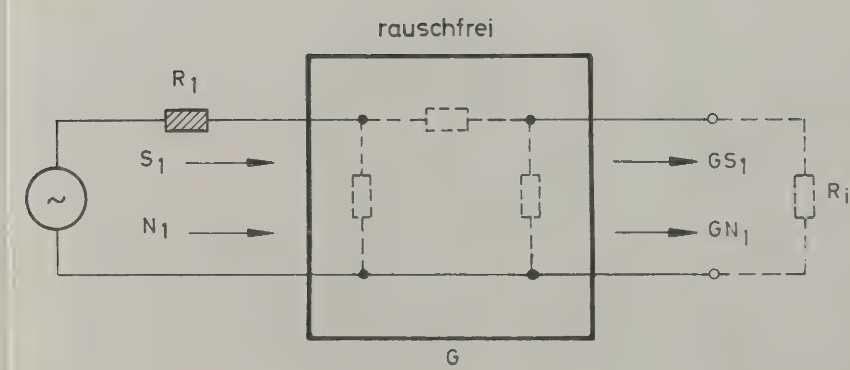
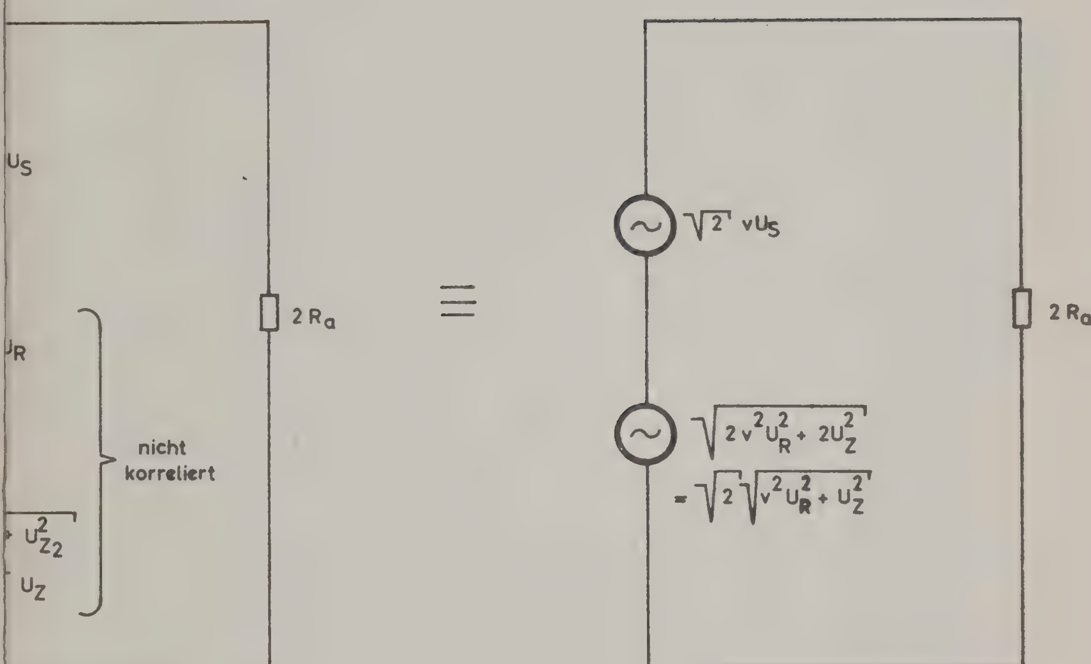

rauschfrei
R1
S1
N1
GS1
GN1
Ri
G

Bild 6



$$\frac{U_S^2}{\ldots a} = \frac{v^2\, U_S^2}{R_a}\ ;$$

R 12874
Bl.28

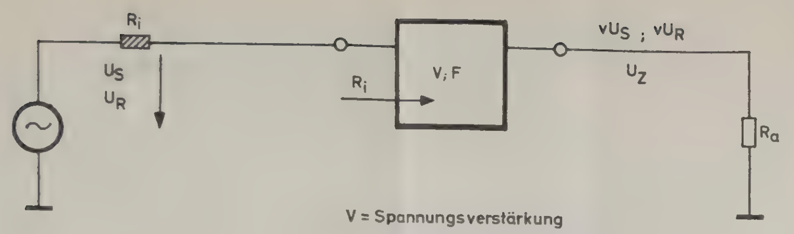
$$\frac{\ldots U_R^2 + U_Z^2)}{R_a} = \frac{v^2 U_R^2 + U_Z^2}{R_a}\ ;$$

$$\boxed{F = \frac{U_S^2}{U_R^2} \cdot \frac{v^2 U_R^2 + U_Z^2}{v^2 U_S^2} = 1 + \frac{U_Z^2}{v^2 U_R^2}\ .}$$

Bild 7 Rauschverhalten von Vierpolen

Bild 7

1)



V = Spannungsverstärkung

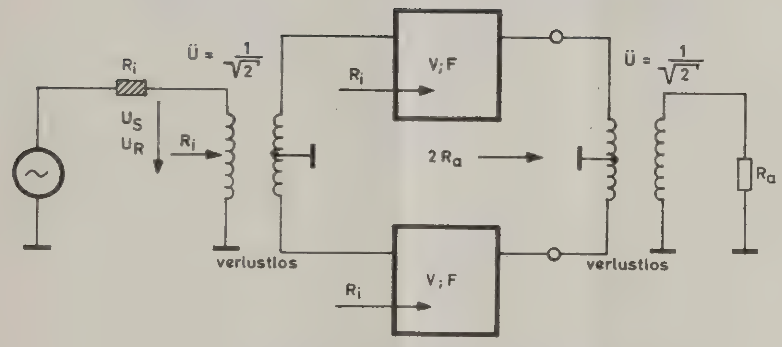
Rauschzahl des Grundvierpols

$$S_1 = \frac{U_S^2}{R_i} \; ; \qquad S_2 = \frac{v^2 U_S^2}{R_a} \; ;$$

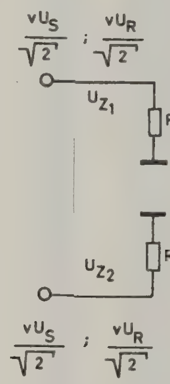
$$N_1 = \frac{U_R^2}{R_i} \; ; \qquad N_2 = \frac{\left(\sqrt{v^2 U_R^2 + U_Z^2}\right)^2}{R_a} \; ;$$

$$\boxed{F = \frac{S_1}{N_1} \cdot \frac{N_2}{S_2} = \frac{U_S^2}{U_R^2} \cdot \frac{v^2 U_R^2 + U_Z^2}{v^2 U_S^2} = 1 + \frac{U_Z^2}{v^2 U_R^2} \; .}$$

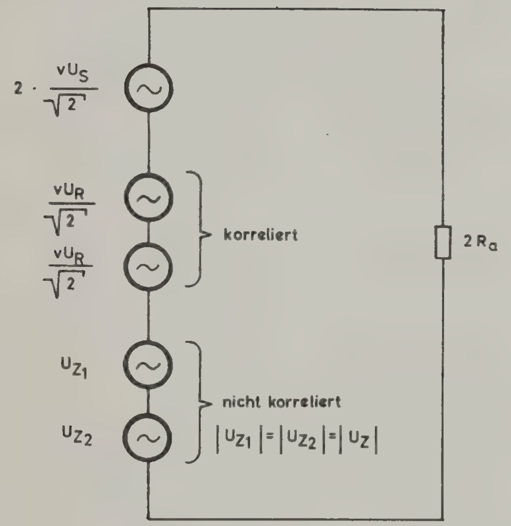
2)



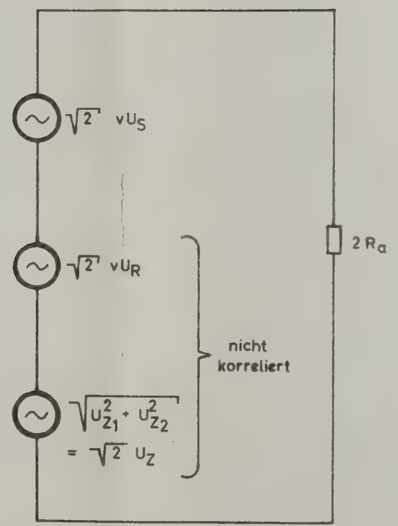
$\equiv$



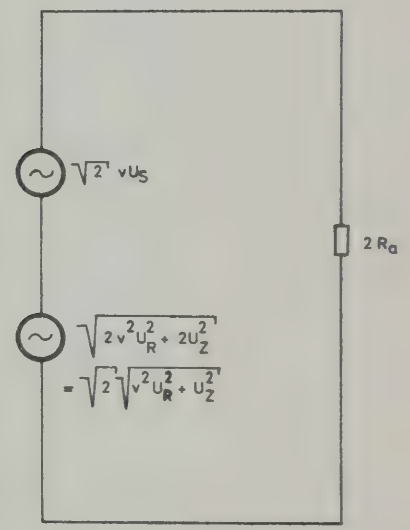
$\equiv$



$\equiv$



$\equiv$



V = Spannungsverstärkung

$$\frac{U_S}{\sqrt{2}} \; ; \longrightarrow S_1 = \frac{U_S^2}{R_i} \; ;$$

$$\frac{U_R}{\sqrt{2}} \; ; \longrightarrow N_1 = \frac{U_R^2}{R_i} \; ;$$

$$S_2 = \frac{2 v^2 U_S^2}{2 R_a} = \frac{v^2 U_S^2}{R_a} \; ;$$

$$N_2 = \frac{2(v^2 U_R^2 + U_Z^2)}{2 R_a} = \frac{v^2 U_R^2 + U_Z^2}{R_a} \; ;$$

$$\boxed{F = \frac{U_S^2}{U_R^2} \cdot \frac{v^2 U_R^2 + U_Z^2}{v^2 U_S^2} = 1 + \frac{U_Z^2}{v^2 U_R^2} \; .}$$

Rauschzahl parallel geschalteter, gleichartiger Vierpole

R 12874
Bl. 28

Bild 7 Rauschverhalten von Vierpolen

Bild 7

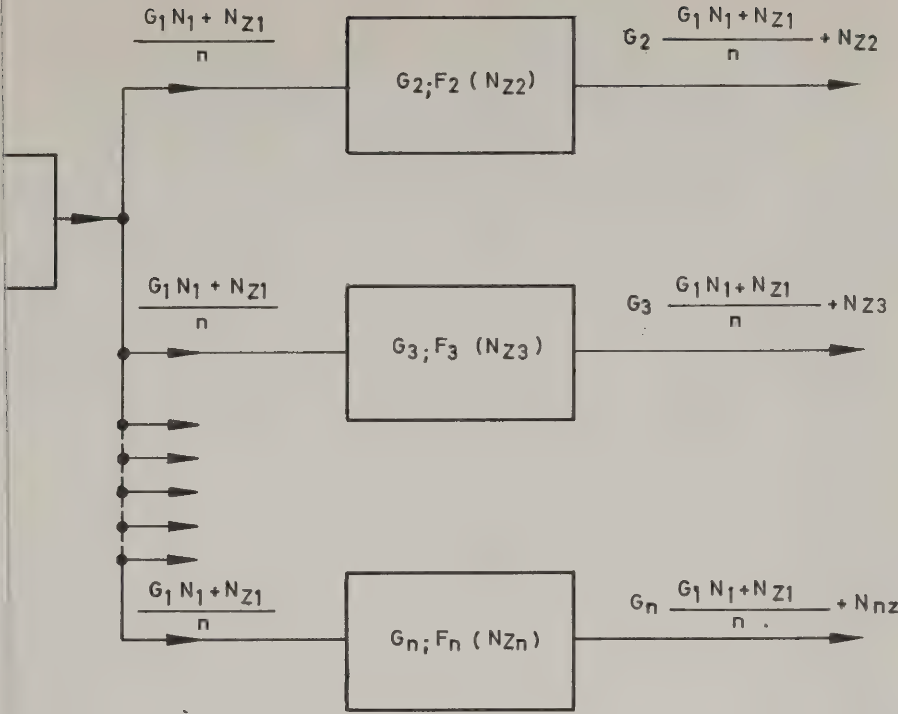
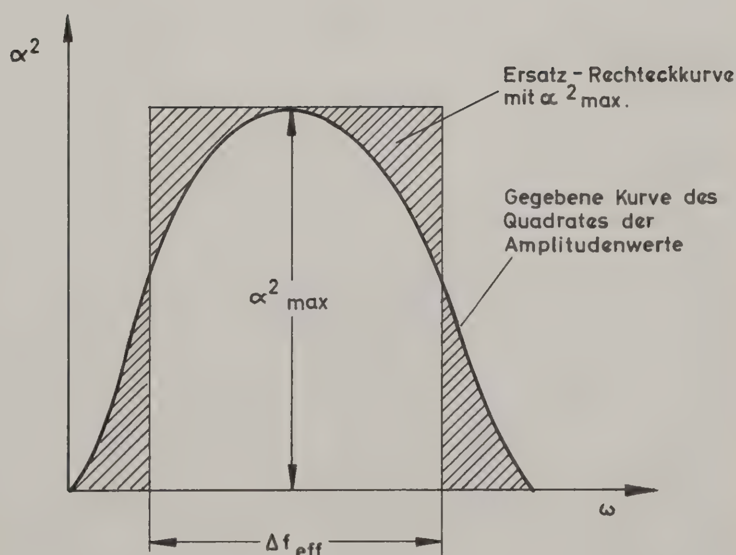


Bild 12



R 12874
Bl. 29

Bild 13

Bild 8....13

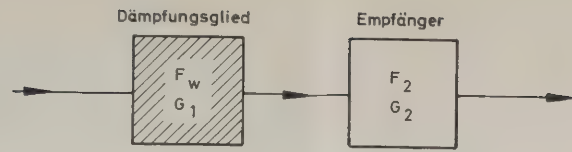


Bild 8

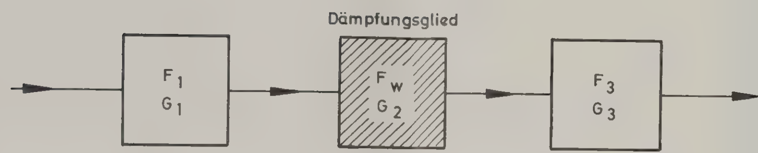


Bild 9

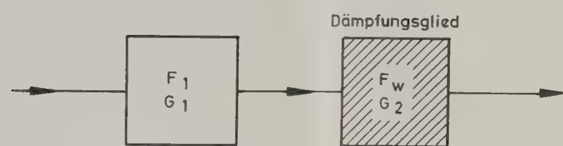


Bild 10

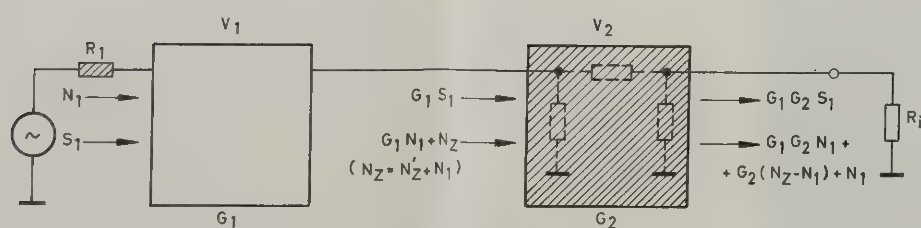


Bild 11

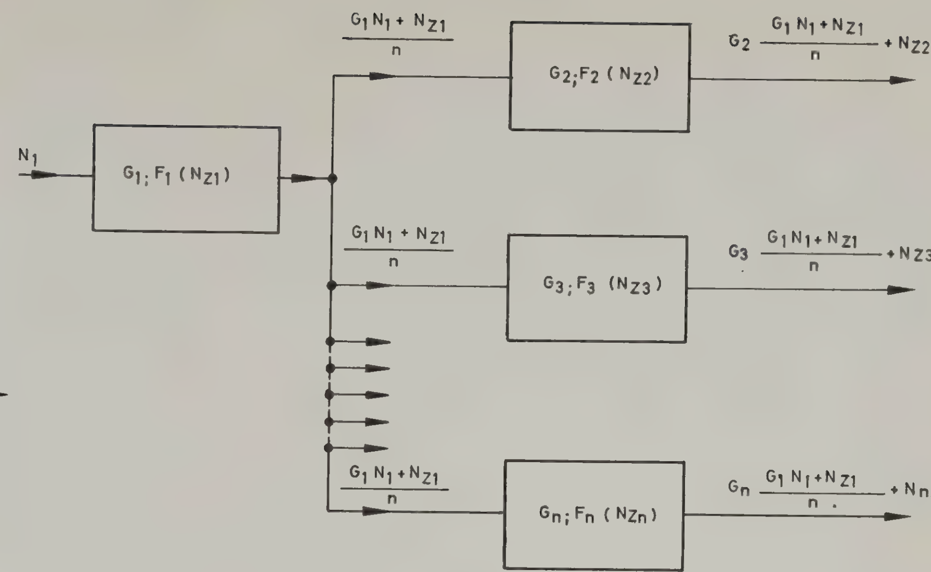


Bild 12

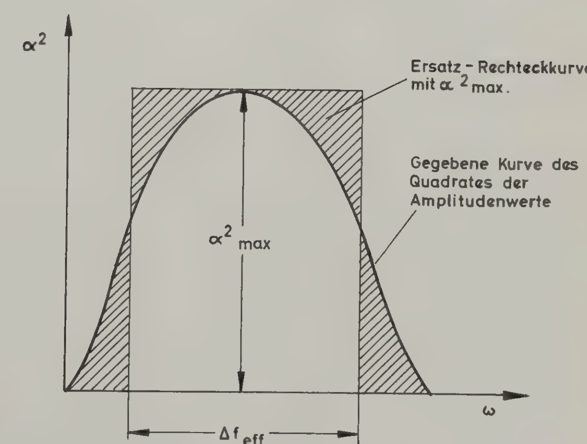


Bild 13

Bild 8....13

3. Maintenance and Repair

3.1 Battery

A built-in nickel-cadmium cell, which is extremely robust and constantly charged during operation, serves as a comparison element for the regulation of the heater current. It is always ready for operation and does not require any maintenance.

If, however, the noise generator is not used for a prolonged period of time (longer than a year) it is possible that the cell has discharged to the point where the voltage is insufficient. This becomes evident when the control is turned fully clockwise and the meter no longer gives full-scale deflection. If this is the case, the noise generator must be operated for approximately one hour with the noise power control turned off to recharge the battery ready for operation. If full-scale deflection is still not obtained the emission of the valve has deteriorated.

3.2 Life Expectancy of the Diode

The average life expectancy of the valve 5722, stated by Sylvania, is plotted vs. the heater voltage in Fig. 14. The curve refers to a 40% reduction of the filament diameter. The SKTU utilizes the heater voltage range up to only approximately 4.9 V. The life expectancy is, therefore, 300 hours for permanent operation at maximum noise power indicated on the meter. It is advisable to operate the noise generator at maximum noise power only as long as is absolutely necessary for the measurement.

3.3 Adjusting the Diode Emission

If full-scale deflection is not obtained with the noise power control turned fully clockwise due to the deterioration of the emission of the diode, adjustment is possible to a certain extent with the aid of the variable resistor R7. R7 is connected in

series with the power control R4 and accessible only after the signal generator has been withdrawn from the cabinet. It is located beside the tapping panel. Turn the power control 9/10 clockwise and adjust the meter to full-scale deflection with R7. This does not affect the calibration of the meter. If the meter cannot be adjusted to full-scale deflection with R7 the diode must be replaced.

3.4 Replacing the Diode

Withdraw the noise generator from the cabinet, loosen the screw of the tension band around the shielding can of the valve and remove the can. The valve is now accessible and may be replaced. The calibration of the meter is not affected by replacing the diode. After the replacement, adjust resistor R7 according to section 3.3 to make sure that the control range and the angle of rotation of the power control coincide and that the control curve remains sufficiently linear.

3.5 Circuit Description

The Noise Generator Type SKTU contains a special diode with a tungsten filament, which operates in the saturation state, for the generation of the continuous frequency spectrum. The noise figure measurement is based on the determination of the diode current (cf. section 3.6).

The saturation current and consequently the noise power are adjusted by varying the diode heating. Automatic regulation of the heating with the aid of transistors prevents AC supply voltage fluctuations from entering into the measurement. Anode supply voltage fluctuations have no influence since the diode operates in the saturation state. The heater voltage, which is derived from the secondary circuit of the transformer Tr1, rectified by Gl 2 and smoothed with C3, is stabilized by a regulator circuit comprising the transistors T1-T2-T3, the resistors R1-R2-R4-R7 and the battery Ba1. It operates as follows:

The diode current which is to be kept constant is tapped ahead of the filter networks C5-R5-C8 and C6-L2-C9, adjusted to the required value with the voltage divider R4-T7 and applied to the base of the transistor T3. The emitter voltage is determined by the voltage of the battery Ba1 and for all practical purposes is constant. The current through transistor T3 is determined by the voltage difference between base and emitter and so it fluctuates in sympathy with the diode anode current changes. Transistor T2 amplifies this further and feeds a corresponding bias voltage to the base of transistor T1 causing the current through T1 to change. Since T1 is connected in series with the filament of the diode it acts like a variable resistor compensating change in the diode current via the heater current.

Moreover, regulation is provided for levelling out AC supply voltage fluctuations. For this the voltage rectified at Gl 2 is tapped ahead of the regulator circuit and applied to the base of the transistor T3 via R2-R4.

The desired noise power is selected with the potentiometer R4 by varying the voltage difference between base and emitter of T3. The adjusted noise power is then kept constant by the regulator circuit.

The stability of the adjusted noise power depends on the value adjusted. The change amounts to less than ±2.5% when the AC supply voltage changes by ±10%. It does not, however, enter into the test result as the meter indicates correctly.

Since the saturation current increases exponentially with the heater power, a potentiometer R4 with an exponentially falling characteristic, has been used. This together with the suitable choice of R7 ensures that the relation between the angle of rotation of R4 and the indication is linear.

The battery Ba1 which supplies the constant emitter voltage is a nickel-cadmium button-size cell of 1.2 V. During operation, even if the power control is turned fully clockwise, a small current flows through the transistor T3 and charges the battery.

3.6 Correlation of Noise Figure and Diode Current

The Noise Generator Type SKTU contains a special diode with a tungsten filament, which operates in the saturation state, for the generation of the continuous frequency spectrum. There is a defined relationship between the saturation and the noise current of this diode and, as a result, if the source impedance is known, also with the available noise power. The noise current is given by the relation

$$I_R = \sqrt{2e \times I_s \times \Delta f}$$

where $e = 1.6 \times 10^{-19}$ Coulomb;

I_s = saturation current of the diode;

Δf = effective noise bandwidth.

If an impedance R_i which is equal to the input impedance R_e of the load is connected in parallel with this diode the noise power obtained is

$$N_R = \left(\frac{I_R}{2}\right)^2 \times R_i = e/2 \times I_s \times \Delta f \times R_i .$$

Hence, referred to a bandwidth of 1 Hz

$$\frac{N_R}{\Delta f} = e/2 \times I_s \times R_i .$$

If

$$\frac{N_R}{\Delta f} = kT_o \times F$$

the noise figure becomes

$$F = \frac{e \times I_s \times R_i}{2\ kT_o} .$$

If the values for e and kT_o are inserted

$$F = 20 \times \frac{I_s}{A} \times \frac{R_i}{\Omega} .$$

In this way, the determination of the noise figure is reduced to a simple measurement of the diode current (cf. Fig. 15).

Translations for Parts Lists

Anschlußkabel	Connecting cable
Drehspul-Strommesser	Moving-coil meter
Elektrolyt-Kondensator	Electrolytic capacitor
Gleichrichter	Rectifier
HF-Kippschalter	RF toggle switch
Hochfr.-Drossel	RF choke
Instrumentwiderstand	Instrument resistor
Klatschkondensator	Bypass capacitor
MP-Kondensator	MP capacitor
Netzschalterkombinat.	Power switch assembly
Netztransformator	Power transformer
Papier-Df-Kondensator	Feed-through paper capacitor
Papierkondensator	Paper capacitor
Rausch-Diode	Noise diode
Schaltteilliste	Parts list
Schicht-Drehwiderstand	Variable depos.-carbon resistor
Schichtwiderstand	Depos.-carbon resistor/Film resistor
Schmelzeinsatz	Fuse
SHF-Meßwiderstand	SHF precision termination
Spannungswähler	Tapping panel (Fuse strip)
Stahlakkumulator	Steel accumulator
Transistor	Transistor
Zwergglimmlampe	Miniature glow lamp

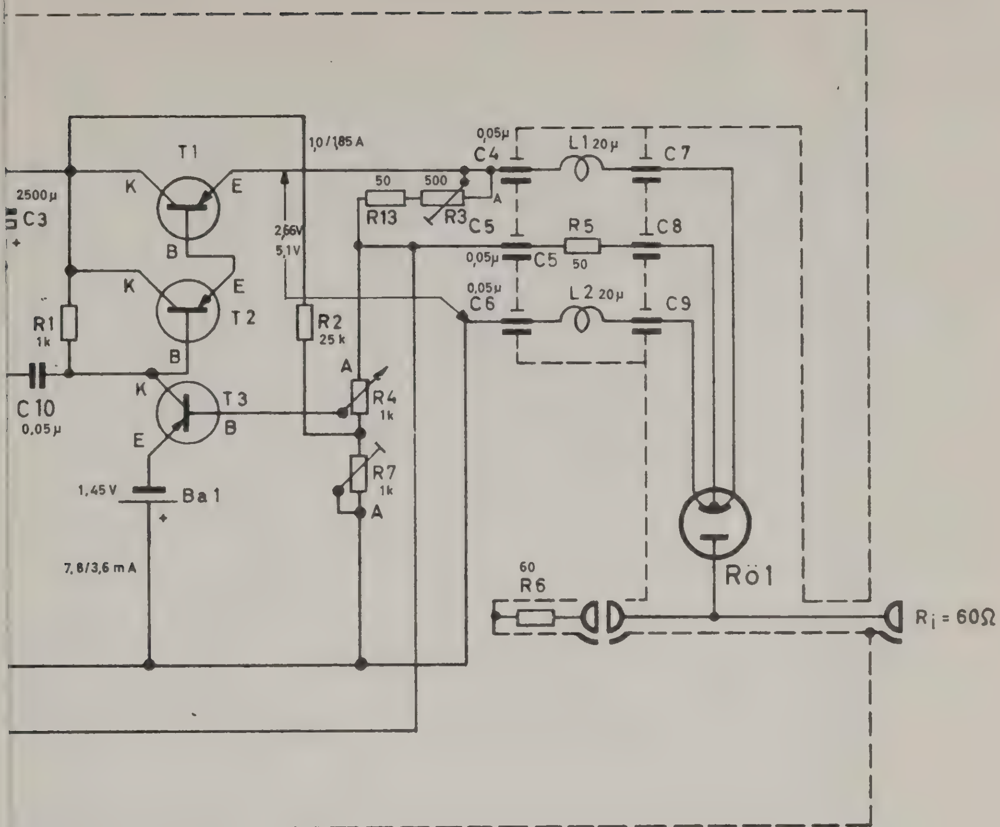
3.7. Schaltteilliste

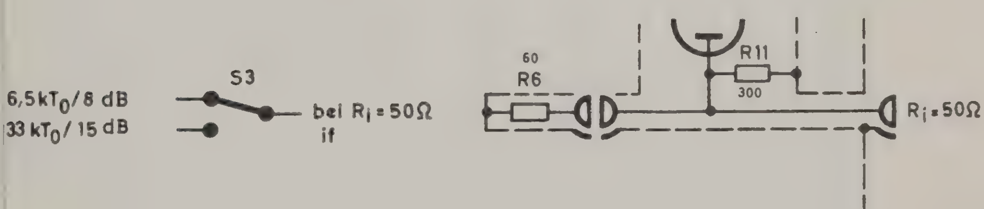
(ÄZ „h" Nr. 11087)

Kenn-zei-chen	Benennung	Wert	R&S-Sach-Nr.
Ba1	Stahlakkumulator		BA 30013
C1	MP-Kondensator	8 µF/250 V	CMR 8/250
C2	MP-Kondensator	8 µF/250 V	CMR 8/250
C3	Elektrolytkondensator	2500 µF/35 V	CEE 21/2500/35
C4	Papier-Df-Kondensator	50 000 pF/300 V	CPD 50 000/300
C5	Papier-Df-Kondensator	50 000 pF/300 V	CPD 50 000/300
C6	Papier-Df-Kondensator	50 000 pF/300 V	CPD 50 000/300
C7	Klatschkondensator		enth. in 4151 - 1.1
C8	Klatschkondensator		enth. in 4151 - 1.1
C9	Klatschkondensator		enth. in 4151 - 1.1
C10	Papierkondensator	47 000 pF/250 V	CPK 58003 n 47
Gl 1	Gleichrichter	250 V/100 mA	GNB 76341
Gl 2	Gleichrichter	30 V/2000 mA	GNB 11/30/2000 B
I1	Drehspul-Strommesser		INS 40504 für BN 4151/2/50 INS 40505 für BN 4151/2/60 INS 40506 für BN 4151/2/75
K1	Anschlußkabel		LKA 08031/1

Kenn-zei-chen	Benennung	Wert	R&S-Sach-Nr.
L1	Hochfr.-Drossel		DUF 311/20
L2	Hochfr.-Drossel		DUF 311/20
R1	Schichtwiderstand	1 kΩ/0,25 W	WFE 321 k 1
R2	Schichtwiderstand	etwa 25 kΩ/0,25 W	WFE 321 k ...
R3	Schicht-Drehwiderst.	500 Ω lin.	WS 9122 F/500
R4	Schicht-Drehwiderst.	1 kΩ log.	WS 5326/1 k
R5	Schichtwiderstand	50 Ω/0,25 W	WFE 321 E 50
R6	SHF-Meßwiderstand Type RMC	60 Ω	33527/60
R7	Schicht-Drehwiderst.	1 kΩ lin.	WS 9122 F/1 k
R8	Instrumentwiderstand		IZ 102/6,66 mA/ 33,3 mA (0,5)
R9	Schichtwiderstand	25 kΩ/2 W	WF 25 k/2
R10	Schichtwiderstand	500 Ω/2 W	WF 500/2
R11	Schichtwiderstand	300 Ω/0,05 W	WFK 613/300/0,05 für BN 4151/2/50
R12	Schichtwiderstand	16 Ω/0,25 W	WFK 633/16/0,25 für BN 4151/2/75
R13	Schichtwiderstand	50 Ω/0,25 W	WFE 321 E 50
Rl 1	Zwergglimmlampe	220 V	RL 210
Rö1	Rausch-Diode		Sylvania 5722

Kenn-zei-chen	Benennung	Wert	R&S-Sach-Nr.
S1	Netzschalterkombinat.		SKK 120
S2	Spannungswähler		FD 60511
S3	HF-Kippschalter		SR 301/2
Si1	Schmelzeinsatz	400 mA (für 220/235 V)	M 0,4 C DIN 41571
Si2	Schmelzeinsatz	100 mA	M 0,1 C DIN 41571
T1	Transistor		GT/AD 130/V
T2	Transistor		GT/AC 124
T3	Transistor		GT/AC 124
Tr1	Netztransformator		4151 - 21





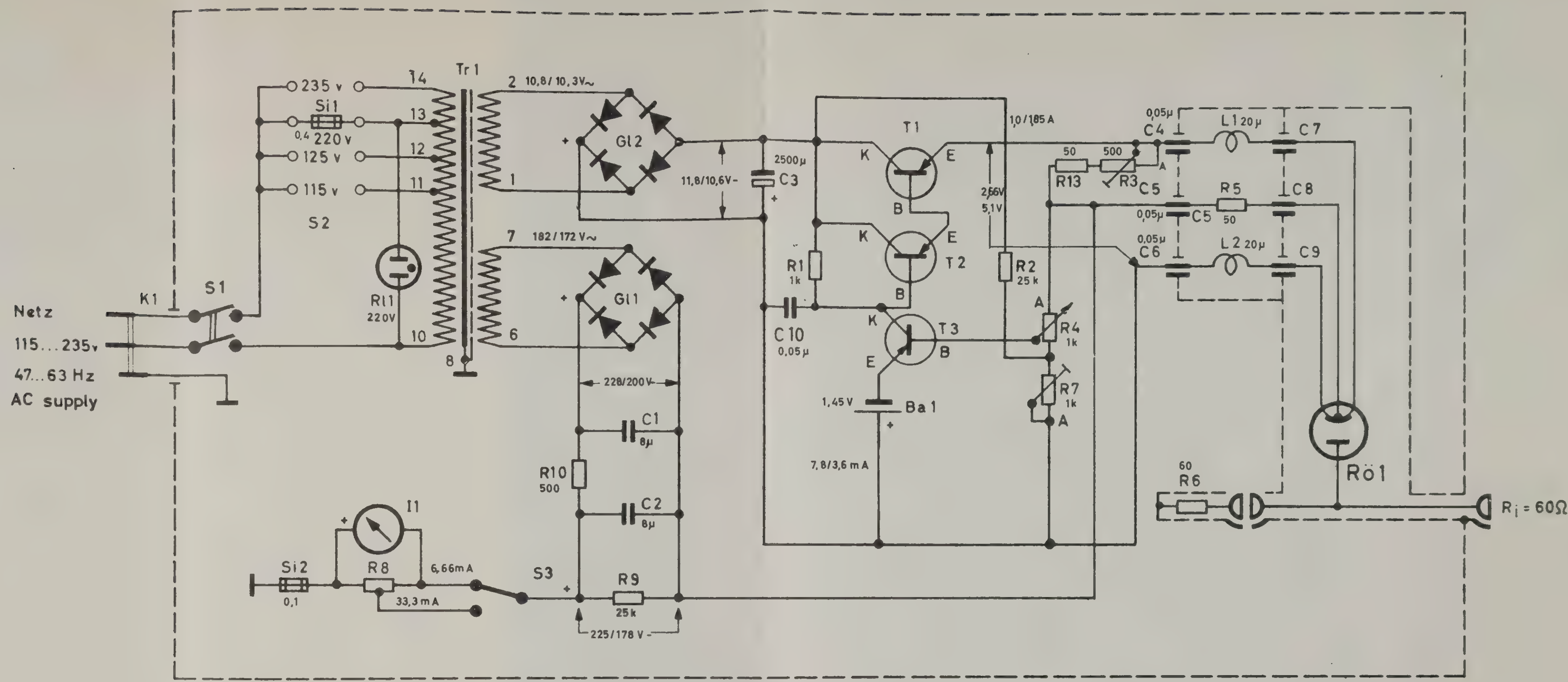
Spannungswerte gemessen mit hochohmigem Instrument bei Einstellung auf 32...40 kT_0

Voltage measured with high-impedance meter adjusted for 32 to 40 kT_0

Stromlauf

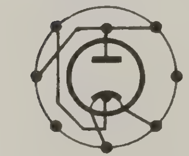
Circuit Diagram

2874



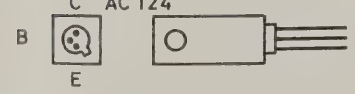
Rö1

Sylvania 5722



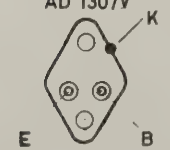
T 2,3

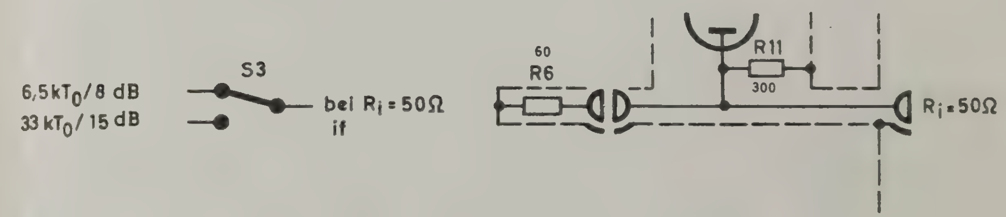
AC 124

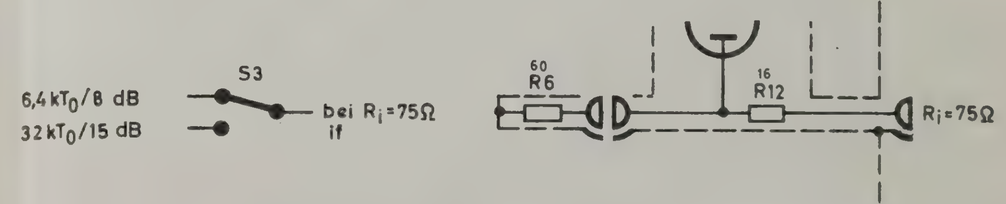


T1

AD 130/V







Spannungswerte gemessen mit hochohmigem Instrument bei Einstellung auf 32...40 kT_0

Voltage measured with high-impedance meter adjusted for 32 to 40 kT_0

Stromlauf

Circuit Diagram

2874

?A

Translations for Figs. 14 and 15

Bild 14	Fig. 14
Heizspannung	Heater voltage
Lebensdauer	Life expectancy

Bild 15	Fig. 15

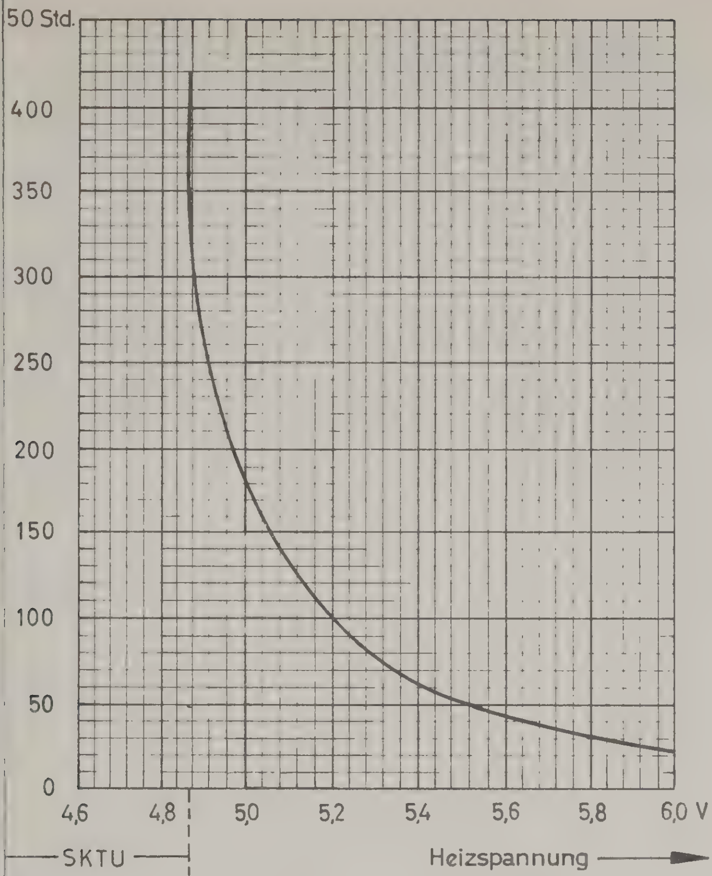


Bild 14

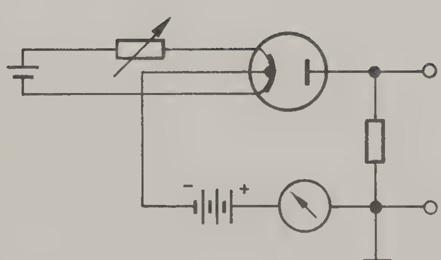


Bild 15

Bild 14 und 15

12874
.39

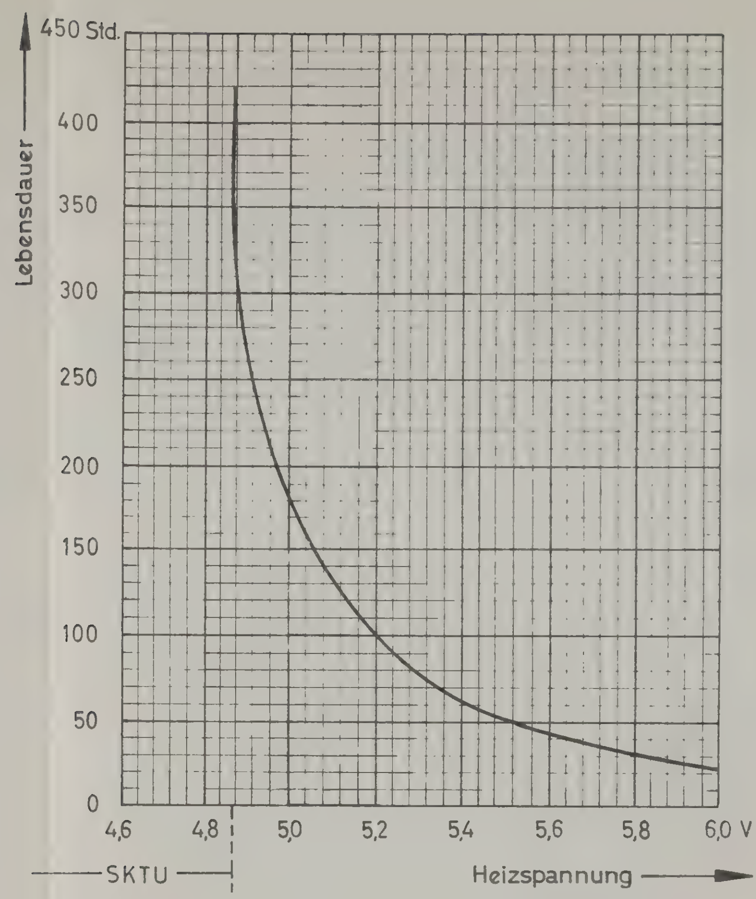


Bild 14

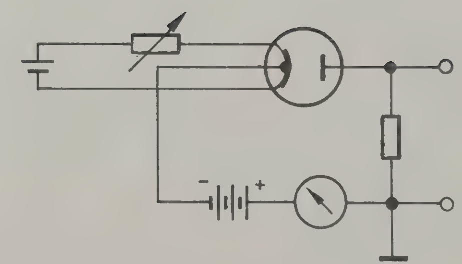


Bild 15

Bild 14 und 15

12874
.39

Zusammenstell-Vorschrift Nr. R 15811

zur ~~deutschen~~ englischen Geräte ~~Grundgeräte Einschub Zusatzgeräte Baugruppen Einsatz Rahmen~~ ~~Anlagen~~ - Beschreibung für

Typ SKTU

BN 4151/2/50
4151/2/60
4151/2/75

FNr. M 1409/1...75
M 1451/1...100

Zusammenstellung .... nach Pos.-Nr.

Umschlag .... Karton mit Rückenbindung
~~Kunststoffordner 40 mm~~
~~Kunststoffordner 60 mm~~
~~ohne, dafür 4fachlochung mit Banderole~~

Umschlagbeschriftung .... ~~auf 1 Seite nach Vorlage R~~
~~auf Rücken nach Vorlage R~~

Register .... ~~Nr. 4319 (1...10)~~
~~Nr. 4320 (11...20)~~
~~Nr. 4321 (21...30)~~
~~Nr. 4322 (31...40)~~

Pos.-Nr.	Teil	Sach-Nr.	Blatt-Nr.	ÄZ	Bemerkung
1	Titelblatt	R 15666	1		
2	Hinweisblatt	R 14500			
3	Beschreibung	R 15666	2...8		
4	Zeichnung	R 12874	8		
5	Beschreibung	R 15666	9...24		
6	Übers.-Liste	R 15666	29...31		
7	Zeichnungen	R 12874	25...29		
8	Beschreibung	R 15666	25...28		
9	Übers.-Liste	R 15666	32		
10	Schaltteilliste	R 12874	35...37		
11	Stromlauf	R 12874	38		
12	Übers.-Liste	R 15666	33		
13	Zeichnung	R 12874	39		
14	Zus.-Vorschrift	R 15811			

5 KWB	Name	Datum
bearb.	Berger	7.1.69
geschr.	Mendicka	8.1.69
geprüft	Bg.	15.1.69

Liste besteht aus 1 Blatt

R 15811